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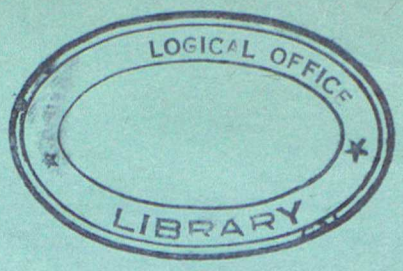


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METEOROLOGICAL OFFICE

London Road, Bracknell, Berkshire.

APPENDIX TO

# HYDROLOGICAL MEMORANDUM No 38

## The calculation of actual evaporation and soil moisture deficit over specified catchment areas.

by

J.Grindley

ORGS UKMO H

National Meteorological Library
FitzRoy Road, Exeter, Devon. EX1 3PB

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## The calculation of actual evaporation and soil moisture deficit over specified catchment areas

Since 1962 the Meteorological Office has been publishing maps of soil moisture deficit over Great Britain. The method of preparing the maps has been discussed in detail by Grindley [1] and is outlined more briefly in the explanatory notes which accompany the first issue of the maps in each spring.

Basically, estimates of soil moisture deficit are obtained by taking the difference between rainfall and evaporation. When evaporation exceeds rainfall, vegetation has to draw on the reserves of moisture in the soil to satisfy transpiration requirements and when this occurs a soil moisture deficit is considered to have been set up.

In assessing soil moisture deficits account must be taken of the fact that vegetation has increasing difficulty in extracting moisture from the soil (because of increasing soil moisture tension) as accumulated potential evaporation becomes greater than accumulated rainfall.

The question of the manner and extent to which actual evaporation (hence soil moisture deficit) begins to fall below the potential is extremely controversial and has been discussed extensively in the literature. Some models postulate a divergence between potential and actual evaporation, at a rate proportional to the remaining soil moisture, as soon as a deficit is set up; other models postulate a linear divergence sometimes with threshold values at which the rate of divergence increases sharply to some arbitrary proportion of the earlier rate and yet others suppose evaporation to continue at near potential rate until wilting point is reached when actual evaporation drops to near nil.

The model used in the hydrological branch of the Meteorological Office is that proposed by Penman in his paper "The dependence of transpiration on soil and weather conditions" [2], where the concept of root constant was introduced. The root constant defines a specified amount of soil moisture (expressed in equivalent depth in inches) which can be extracted from the soil without difficulty by a given vegetation type on a given soil. A further inch of moisture can be extracted with increasing difficulty and extraction thereafter becomes minimal.

In assessing areal soil moisture deficits and actual evaporation, account must be taken of different forms of land use within the area. Again many models have been proposed by different workers to allow for this multicapacity catchment accounting. The model used for the preparation of the soil moisture deficit maps is that adopted by Penman in his classic paper on the water balance of the Stour catchment area [3], where 50 per cent of the area is considered to carry short-rooted vegetation (such as grass) with a mean root constant of 3 inches, 30 per cent of the area is considered to carry long-rooted vegetation (such as trees) with a root constant of 8 inches and 20 per cent of the area is considered riparian where the permanent ground-water table is sufficiently near the surface to maintain potential evaporation at all times. The assumption is that each of the stations used in the soil moisture deficit network (about 200) represents a unit catchment area having this generalised distribution.

It was apparent from the start that when studying specific catchment areas account must be taken of land use within the catchment and recently more sophisticated models have been used for this purpose in the hydrology branch of the Meteorological Office.

Advice was obtained from the agricultural branch of the Office on the maximum amount of water likely to be extracted before wilting became permanent. These amounts for a wide variety of crops are shown in Table. 1. The agricultural

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branch of the Office adopts a simpler model for calculating how much actual soil moisture deficit has fallen below the potential, viz the potential rate is assumed until half the maximum deficit has been attained when the rate of extraction drops sharply to half the potential rate until the maximum deficit obtains.

This approach is perfectly adequate for most farming practice but it was felt that deviations between actual and potential deficits gradually increasing at first and then increasing very rapidly was probably more realistic physically and should be retained for catchment studies. Accordingly the maximum deficits shown in Table 1 have been equated with root constants as follows:

| Maximum soil moisture deficit in. | root constant in. |
|---|---|
| 10 | 8.0 |
| 8 | 5.5 |
| 6 | 3.8 |
| 5 | 3.0 |
| 4 | 2.2 |
| 2 | 0.5 |

The amount by which actual evaporation falls below the potential for each root constant has been expressed in tabular form (following the graph in reference 2) and is shown in Tables 2-7.

The root constants, of course, refer strictly to vegetation type and make no reference to soil type, except in so far that the soil type is reflected in the vegetation which it carries. Where soils are known to be poor allowance can be made by reducing the root constant.

Certain seasonal restrictions on evaporation are imposed for different vegetation cover and other forms of land use are also taken into account as follows:

1. Bare ground, fallow etc. It is assumed that evaporation takes place at the potential rate until 1 inch of moisture has been extracted when evaporation ceases until more rain has fallen.

2. Riparian area. Evaporation always takes place at the potential rate.

3. Open water. Evaporation is considered to be 20 per cent higher than the potential evaporation from a vegetated surface.

4. Urban areas. These are taken to be the areas coloured grey on the 1-inch OS map. It is assumed that 25 per cent of the area so obtained is waterproofed (pavements, roofs etc.). Evaporation from the waterproofed zone is considered to occur only on days of rainfall and is taken to be the rainfall or potential evaporation whichever is smaller.

5. After harvest (conventional date 1st August) it is assumed that evaporation from cereal areas takes place as from fallow ground.

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6. For certain crops when ground cover is incomplete in the spring it is assumed that evaporation takes place at $\frac{2}{3}$ the potential rate until cover is complete (conventional date 1st May). The proviso is made that up to 1 inch may evaporate at the potential rate (as with bare ground).

7. Rough grazing. An upper limit of 2 inches extractable water is imposed.

Details of land use for a particular area may be obtained from a variety of sources; the Ministry of Agriculture, Fisheries and Food for crop distribution, the Land Classification Map (published HMSO), the Geological Section of the Water Resources Board for delineation of riparian zones, the Land Use of Britain (Geographical Publications Ltd.) for discussion of land use regions within counties. An Agricultural Atlas of England and Wales [4] gives generalised but very useful maps of crop and grass distribution.

A typical example of distribution of land use (for an area in north-west England) is:

| | Root-constant in. | % of total area |
|---|---|---|
| Cereals etc. | 5.5 | 14.7 |
| Root crops, etc. | 3.8 | 3.3 |
| Permanent grass, etc. | 3.0 | 39.4 |
| Temporary grass, etc. | 2.2 | 16.7 |
| Rough grazing | 0.5 | 10.7 |
| Woodland | 8.0 | 1.7 |
| Fallow | | 0.4 |
| Urban | | 7.2 |
| Riparian | | 4.1 |
| Open water | | 1.8 |
| | | 100.0 |

References

1. Grindley J. The estimation of soil moisture deficits. Met. Mag. London, Vol 96, 1967, p. 97.

2. Penman H.L. The dependence of transpiration on weather and soil conditions. Jnl. Soil Sci. Oxford, 1, 1949, p. 74.

3. Penman H.L. The water balance of the Stour catchment area. Jnl. Instn. Wat. Engrs., London 4, 1950, p. 457.

4. An Agricultural Atlas of England and Wales. 1964. J.T. Coppock. Published Faber and Faber Ltd., London.

Table 1

Land Utilization Survey

| | Crops | Maximum SMD | Actual |
|---|---|---|---|
| 1 | Wheat | 8 | |
| 2 | Barley | 8 | |
| 3 | Oats | 8 | |
| 4 | Mixed Corn | 8 | |
| 5 | Rye | 8 | |
| 6 | Potatoes, first early varieties | 4 | |
| 7 | Potatoes, maincrop and second earlies | 6 | |
| 8 | Beans and Peas | 4 | |
| 9 | Turnips, Swedes and Fodder Beet | 6 | |
| 10 | Mangolds | 6 | |
| 11 | Rape (or Cole) | 5 | |
| 12 | Kale | 5 | |
| 13 | Cabbage, Savoys and Kohl Rabi | 5 | |
| 14 | Mustard | 5 | |
| 15 | Other Crops | 5 | |
| 16 | Sugar Beet (for Sugar) | 6 | |
| 17 | Hops | 8 | |
| 18 | Orchards, grown commercially | 9 | |
| 19 | Orchards, not grown commercially | 8 | |
| 20 | Small fruit, grown commercially | 6 | |
| 21 | Vegetables; Hardy Nursery Stock; Flowers; Crops under Glass | 4 | |
| 22 | Small Fruit and Vegetables, not grown commercially | 4 | |
| 23 | Other Crops | 5 | |
| 24 | Bare Fallow | 1 | |
| 25 | Lucerne | 6 | |
| 26 | Clover, Sainfoin and | 4 | |
| 27 | Temporary Grasses | 4 | |
| 28 | Permanent Grass | 5 | |
| 29 | (excluding rough grazings) | 5 | |
| 30 | ROUGH GRAZINGS | 2 | |
| | PERMANENT WOODLAND (Not Listed) | 10 but 5 on poor land | |

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Table 2

## DERIVATION OF ACTUAL EVAPORATION FROM POTENTIAL FOR A ROOT CONSTANT OF 0.5 INCHES

| Potential in. | Actual in. | Potential in. | Actual in. |
|---|---|---|---|
| 1.30 | 1.30 | 2.02-2.03 | 1.67 |
| 1.31 | 1.30 | 2.04-2.06 | 1.68 |
| 1.32 | 1.31 | 2.07-2.08 | 1.69 |
| 1.33-1.34 | 1.32 | 2.09-2.11 | 1.70 |
| 1.35 | 1.33 | 2.12-2.13 | 1.71 |
| 1.36-1.37 | 1.34 | 2.14-2.16 | 1.72 |
| 1.38-1.39 | 1.35 | 2.17-2.19 | 1.73 |
| 1.40-1.41 | 1.36 | 2.20-2.22 | 1.74 |
| 1.42- | 1.37 | 2.23-2.25 | 1.75 |
| 1.43-1.44 | 1.38 | 2.26-2.28 | 1.76 |
| 1.45-1.46 | 1.39 | 2.29-2.31 | 1.77 |
| 1.47 | 1.40 | 2.32.2.34 | 1.78 |
| 1.48-1.49 | 1.41 | 2.35-2.37 | 1.79 |
| 1.50-1.51 | 1.42 | 2.38-2.41 | 1.80 |
| 1.52-1.53 | 1.43 | 2.42-2.44 | 1.81 |
| 1.54-1.55 | 1.44 | 2.45-2.48 | 1.82 |
| 1.56 | 1.45 | 2.49-2.51 | 1.83 |
| 1.57-1.58 | 1.46 | 2.52-2.55 | 1.84 |
| 1.59-1.60 | 1.47 | 2.56-2.60 | 1.85 |
| 1.61-1.62 | 1.48 | 2.61-2.64 | 1.86 |
| 1.63-1.64 | 1.49 | 2.65-2.69 | 1.87 |
| 1.65-1.66 | 1.50 | 2.70-2.74 | 1.88 |
| 1.67-1.68 | 1.51 | 2.75-2.79 | 1.89 |
| 1.69-1.70 | 1.52 | 2.80-2.85 | 1.90 |
| 1.71-1.72 | 1.53 | 2.86-2.92 | 1.91 |
| 1.73-1.74 | 1.54 | 2.93-3.00 | 1.92 |
| 1.75-1.76 | 1.55 | 3.01-3.10 | 1.93 |
| 1.77-1.78 | 1.56 | 3.11-3.27 | 1.94 |
| 1.79-1.80 | 1.57 | 3.28-3.61 | 1.95 |
| 1.81-1.82 | 1.58 | 3.62-3.73 | 1.96 |
| 1.83-1.84 | 1.59 | 3.74-3.85 | 1.97 |
| 1.85-1.87 | 1.60 | 3.86-3.96 | 1.98 |
| 1.88-1.89 | 1.61 | 3.97-4.08 | 1.99 |
| 1.90-1.91 | 1.62 | 4.09-4.20 | 2.00 |
| 1.92-1.93 | 1.63 | | |
| 1.94-1.96 | 1.64 | | |
| 1.97-1.98 | 1.65 | | |
| 1.99-2.01 | 1.66 | | |

Table 3

DERIVATION OF ACTUAL EVAPORATION FROM POTENTIAL FOR A ROOT CONSTANT OF 2.2 INCHES

| Potential in. | Actual in. | Potential in. | Actual in. | Potential in. | Actual in. | Potential in. | Actual in. |
|---|---|---|---|---|---|---|---|
| 3.00 | 3.00 | 3.72-3.73 | 3.37 | 6.38-6.49 | 3.75 | 10.85-10.96 | 4.13 |
| 3.01 | 3.00 | 3.74-3.76 | 3.38 | 6.50-6.60 | 3.76 | 10.97-11.07 | 4.14 |
| 3.02 | 3.01 | 3.77-3.78 | 3.39 | 6.61-6.72 | 3.77 | 11.08-11.19 | 4.15 |
| 3.03-3.04 | 3.02 | 3.79-3.81 | 3.40 | 6.73-6.84 | 3.78 | 11.20-11.31 | 4.16 |
| 3.05 | 3.03 | 3.82-3.83 | 3.41 | 6.85-6.96 | 3.79 | 11.32-11.43 | 4.17 |
| 3.06-3.07 | 3.04 | 3.84-3.86 | 3.42 | 6.97-7.08 | 3.80 | 11.44-11.55 | 4.18 |
| 3.08-3.09 | 3.05 | 3.87-3.89 | 3.43 | 7.09-7.19 | 3.81 | 11.56-11.66 | 4.19 |
| 3.10-3.11 | 3.06 | 3.90-3.92 | 3.44 | 7.20-7.31 | 3.82 | 11.67-11.78 | 4.20 |
| 3.12 | 3.07 | 3.93-3.95 | 3.45 | 7.32-7.43 | 3.83 | 11.79-11.90 | 4.21 |
| 3.13-3.14 | 3.08 | 3.96-3.98 | 3.46 | 7.44-7.55 | 3.84 | 11.91-12.02 | 4.22 |
| 3.15-3.16 | 3.09 | 3.99-4.01 | 3.47 | 7.56-7.66 | 3.85 | 12.03-12.13 | 4.23 |
| 3.17 | 3.10 | 4.02-4.04 | 3.48 | 7.67-7.78 | 3.86 | 12.14-12.25 | 4.24 |
| 3.18-3.19 | 3.11 | 4.05-4.07 | 3.49 | 7.79-7.90 | 3.87 | 12.26-12.37 | 4.25 |
| 3.20-3.21 | 3.12 | 4.08-4.11 | 3.50 | 7.91-8.01 | 3.88 | 12.38-12.49 | 4.26 |
| 3.22-3.23 | 3.13 | 4.12-4.14 | 3.51 | 8.02-8.13 | 3.89 | 12.50-12.60 | 4.27 |
| 3.24-3.25 | 3.14 | 4.15-4.18 | 3.52 | 8.14-8.25 | 3.90 | 12.61-12.72 | 4.28 |
| 3.26- | 3.15 | 4.19-4.21 | 3.53 | 8.26-8.37 | 3.91 | 12.73-12.84 | 4.29 |
| 3.27-3.28 | 3.16 | 4.22-4.25 | 3.54 | 8.38-8.49 | 3.92 | 12.85-12.96 | 4.30 |
| 3.29-3.30 | 3.17 | 4.26-4.30 | 3.55 | 8.50-8.60 | 3.93 | 12.97-13.07 | 4.31 |
| 3.31-3.32 | 3.18 | 4.31-4.34 | 3.56 | 8.61-8.72 | 3.94 | 13.08-13.19 | 4.32 |
| 3.33-3.34 | 3.19 | 4.35-4.39 | 3.57 | 8.73-8.84 | 3.95 | 13.20-13.31 | 4.33 |
| 3.35-3.36 | 3.20 | 4.40-4.44 | 3.58 | 8.85-8.96 | 3.96 | 13.32-13.43 | 4.34 |
| 3.37-3.38 | 3.21 | 4.45-4.49 | 3.59 | 8.97-9.08 | 3.97 | 13.44-13.55 | 4.35 |
| 3.39-3.40 | 3.22 | 4.50-4.55 | 3.60 | 9.09-9.19 | 3.98 | 13.56-13.66 | 4.36 |
| 3.41-3.42 | 3.23 | 4.56-4.62 | 3.61 | 9.20-9.31 | 3.99 | 13.67-13.78 | 4.37 |
| 3.43-3.44 | 3.24 | 4.63-4.70 | 3.62 | 9.32-9.43 | 4.00 | 13.79-13.90 | 4.38 |
| 3.45-3.46 | 3.25 | 4.71-4.80 | 3.63 | 9.44-9.55 | 4.01 | 13.91-14.02 | 4.39 |
| 3.47-3.48 | 3.26 | 4.81-4.97 | 3.64 | 9.56-9.66 | 4.02 | 14.03-14.13 | 4.40 |
| 3.49-3.50 | 3.27 | 4.98-5.31 | 3.65 | 9.67-9.78 | 4.03 | 14.14-14.25 | 4.41 |
| 3.51-3.52 | 3.28 | 5.32-5.43 | 3.66 | 9.79-9.90 | 4.04 | 14.26-14.37 | 4.42 |
| 3.53-3.54 | 3.29 | 5.44-5.55 | 3.67 | 9.91-10.02 | 4.05 | 14.38-14.49 | 4.43 |
| 3.55-3.57 | 3.30 | 5.56-5.66 | 3.68 | 10.03-10.13 | 4.06 | 14.50-14.60 | 4.44 |
| 3.58-3.59 | 3.31 | 5.67-5.78 | 3.69 | 10.14-10.25 | 4.07 | 14.61-14.72 | 4.45 |
| 3.60-3.61 | 3.32 | 5.79-5.90 | 3.70 | 10.26-10.37 | 4.08 | 14.73-14.84 | 4.46 |
| 3.62-3.63 | 3.33 | 5.91-6.02 | 3.71 | 10.38-10.49 | 4.09 | 14.85-14.96 | 4.47 |
| 3.64-3.66 | 3.34 | 6.03-6.13 | 3.72 | 10.50-10.60 | 4.10 | 14.97-15.07- | 4.48 |
| 3.67-3.68 | 3.35 | 6.14-6.25 | 3.73 | 10.61-10.72 | 4.11 | 15.08-15.19 | 4.49 |
| 3.69-3.71 | 3.36 | 6.26-6.37 | 3.74 | 10.73-10.84 | 4.12 | | |

Table 4

DERIVATION OF ACTUAL EVAPORATION FROM POTENTIAL FOR A ROOT CONSTANT OF 3 INCHES

| Potential in. | Actual in. | Potential in. | Actual in. | Potential in. | Actual in. | Potential in. | Actual in. |
|---|---|---|---|---|---|---|---|
| 3.80 | 3.80 | 4.52-4.53 | 4.17 | 7.18-7.29 | 4.55 | 11.65-11.76 | 4.93 |
| 3.81 | 3.80 | 4.54-4.56 | 4.18 | 7.30-7.40 | 4.56 | 11.77-11.87 | 4.94 |
| 3.82 | 3.81 | 4.57-4.58 | 4.19 | 7.41-7.52 | 4.57 | 11.88-11.99 | 4.95 |
| 3.83-3.84 | 3.82 | 4.59-4.61 | 4.20 | 7.53-7.64 | 4.58 | 12.00-12.11 | 4.96 |
| 3.85 | 3.83 | 4.62-4.63 | 4.21 | 7.65-7.76 | 4.59 | 12.12-12.23 | 4.97 |
| 3.86-3.87 | 3.84 | 4.64-4.66 | 4.22 | 7.77-7.88 | 4.60 | 12.24-12.35 | 4.98 |
| 3.88-3.89 | 3.85 | 4.67-4.69 | 4.23 | 7.89-7.99 | 4.61 | 12.36-12.46 | 4.99 |
| 3.90-3.91 | 3.86 | 4.70-4.72 | 4.24 | 8.00-8.11 | 4.62 | 12.47-12.58 | 5.00 |
| 3.92 | 3.87 | 4.73-4.75 | 4.25 | 8.12-8.23 | 4.63 | 12.59-12.70 | 5.01 |
| 3.93-3.94 | 3.88 | 4.76-4.78 | 4.26 | 8.24-8.35 | 4.64 | 12.71-12.82 | 5.02 |
| 3.95-3.96 | 3.89 | 4.79-4.81 | 4.27 | 8.36-8.46 | 4.65 | 12.83-12.93 | 5.03 |
| 3.97 | 3.90 | 4.82-4.84 | 4.28 | 8.47-8.58 | 4.66 | 12.94-13.05 | 5.04 |
| 3.98-3.99 | 3.91 | 4.85-4.87 | 4.29 | 8.59-8.70 | 4.67 | 13.06-13.17 | 5.05 |
| 4.00-4.01 | 3.92 | 4.88-4.91 | 4.30 | 8.71-8.81 | 4.68 | 13.18-13.29 | 5.06 |
| 4.02-4.03 | 3.93 | 4.92-4.94 | 4.31 | 8.82-8.93 | 4.69 | 13.30-13.40 | 5.07 |
| 4.04-4.05 | 3.94 | 4.95-4.98 | 4.32 | 8.94-9.05 | 4.70 | 13.41-13.52 | 5.08 |
| 4.06 | 3.95 | 4.99-5.01 | 4.33 | 9.06-9.17 | 4.71 | 13.53-13.64 | 5.09 |
| 4.07-4.08 | 3.96 | 5.02-5.05 | 4.34 | 9.18-9.29 | 4.72 | 13.65-13.76 | 5.10 |
| 4.09-4.10 | 3.97 | 5.06-5.10 | 4.35 | 9.30-9.40 | 4.73 | 13.77-13.87 | 5.11 |
| 4.11-4.12 | 3.98 | 5.11-5.14 | 4.36 | 9.41-9.52 | 4.74 | 13.88-13.99 | 5.12 |
| 4.13-4.14 | 3.99 | 5.15-5.19 | 4.37 | 9.53-9.64 | 4.75 | 14.00-14.11 | 5.13 |
| 4.15-4.16 | 4.00 | 5.20-5.24 | 4.38 | 9.65-9.76 | 4.76 | 14.12-14.23 | 5.14 |
| 4.17-4.18 | 4.01 | 5.25-5.29 | 4.39 | 9.77-9.88 | 4.77 | 14.24-14.35 | 5.15 |
| 4.19-4.20 | 4.02 | 5.30-5.35 | 4.40 | 9.89-9.99 | 4.78 | 14.36-14.46 | 5.16 |
| 4.21-4.22 | 4.03 | 5.36-5.42 | 4.41 | 10.00-10.11 | 4.79 | 14.47-14.58 | 5.17 |
| 4.23-4.24 | 4.04 | 5.43-5.50 | 4.42 | 10.12-10.23 | 4.80 | 14.59-14.70 | 5.18 |
| 4.25-4.26 | 4.05 | 5.51-5.60 | 4.43 | 10.24-10.35 | 4.81 | 14.71-14.82 | 5.19 |
| 4.27-4.28 | 4.06 | 5.61-5.77 | 4.44 | 10.36-10.46 | 4.82 | 14.83-14.93 | 5.20 |
| 4.29-4.30 | 4.07 | 5.78-6.11 | 4.45 | 10.47-10.58 | 4.83 | 14.94-15.05 | 5.21 |
| 4.31-4.32 | 4.08 | 6.12-6.23 | 4.46 | 10.59-10.70 | 4.84 | 15.06-15.17 | 5.22 |
| 4.33-4.34 | 4.09 | 6.24-6.35 | 4.47 | 10.71-10.82 | 4.85 | 15.18-15.29 | 5.23 |
| 4.35-4.37 | 4.10 | 6.36-6.46 | 4.48 | 10.83-10.93 | 4.86 | 15.30-15.40 | 5.24 |
| 4.38-4.39 | 4.11 | 6.47-6.58 | 4.49 | 10.94-11.05 | 4.87 | 15.41-15.52 | 5.25 |
| 4.40-4.41 | 4.12 | 6.59-6.70 | 4.50 | 11.06-11.17 | 4.88 | 15.53-15.64 | 5.26 |
| 4.42-4.43 | 4.13 | 6.71-6.82 | 4.51 | 11.18-11.29 | 4.89 | 15.65-15.76 | 5.27 |
| 4.44-4.46 | 4.14 | 6.83-6.93 | 4.52 | 11.30-11.40 | 4.90 | 15.77-15.87 | 5.28 |
| 4.47-4.48 | 4.15 | 6.94-7.05 | 4.53 | 11.41-11.52 | 4.91 | 15.88-15.99 | 5.29 |
| 4.49-4.51 | 4.16 | 7.06-7.17 | 4.54 | 11.53-11.64 | 4.92 | | |

Table 5

DERIVATION OF ACTUAL EVAPORATION FROM POTENTIAL FOR A ROOT CONSTANT OF 3.8 INCHES

| Potential in. | Actual in. | Potential in. | Actual in. | Potential in. | Actual in. | Potential in. | Actual in. |
|---|---|---|---|---|---|---|---|
| 4.60 | 4.60 | 5.32-5.33 | 4.97 | 7.98-8.09 | 5.35 | 12.45-12.56 | 5.73 |
| 4.61 | 4.60 | 5.34-5.36 | 4.98 | 8.10-8.20 | 5.36 | 12.57-12.67 | 5.74 |
| 4.62 | 4.61 | 5.37-5.38 | 4.99 | 8.21.8.32 | 5.37 | 12.68-12.79 | 5.75 |
| 4.63-4.64 | 4.62 | 5.39-5.41 | 5.00 | 8.33-8.44 | 5.38 | 12.80-12.91 | 5.76 |
| 4.65- | 4.63 | 5.42-5.43 | 5.01 | 8.45-8.56 | 5.39 | 12.92-13.03 | 5.77 |
| 4.66-4.67 | 4.64 | 5.44-5.46 | 5.02 | 8.57-8.68 | 5.40 | 13.04-13.15 | 5.78 |
| 4.68-4.69 | 4.65 | 5.47-5.49 | 5.03 | 8.69-8.79 | 5.41 | 13.16-13.26 | 5.79 |
| 4.70-4.71 | 4.66 | 5.50-5.52 | 5.04 | 8.80-8.91 | 5.42 | 13.27-13.38 | 5.80 |
| 4.72 | 4.67 | 5.53-5.55 | 5.05 | 8.92-9.03 | 5.43 | 13.39-13.50 | 5.81 |
| 4.73-4.74 | 4.68 | 5.56-5.58 | 5.06 | 9.04-9.15 | 5.44 | 13.51-13.62 | 5.82 |
| 4.75-4.76 | 4.69 | 5.59-5.61 | 5.07 | 9.16-9.26 | 5.45 | 13.63-13.73 | 5.83 |
| 4.77 | 4.70 | 5.62-5.64 | 5.08 | 9.27-9.38 | 5.46 | 13.74-13.85 | 5.84 |
| 4.78-4.79 | 4.71 | 5.65-5.67 | 5.09 | 9.39-9.50 | 5.47 | 13.86-13.97 | 5.85 |
| 4.80-4.81 | 4.72 | 5.68-5.71 | 5.10 | 9.51-9.61 | 5.48 | 13.98-14.09 | 5.86 |
| 4.82-4.83 | 4.73 | 5.72-5.74 | 5.11 | 9.62-9.73 | 5.49 | 14.10-14.20 | 5.87 |
| 4.84-4.85 | 4.74 | 5.75-5.78 | 5.12 | 9.74-9.85 | 5.50 | 14.21-14.32 | 5.88 |
| 4.86- | 4.75 | 5.79-5.81 | 5.13 | 9.86-9.97 | 5.51 | 14.33-14.44 | 5.89 |
| 4.87-4.88 | 4.76 | 5.82-5.85 | 5.14 | 9.98-10.09 | 5.52 | 14.45-14.56 | 5.90 |
| 4.89-4.90 | 4.77 | 5.86-5.90 | 5.15 | 10.10-10.20 | 5.53 | 14.57-14.67 | 5.91 |
| 4.91-4.92 | 4.78 | 5.91-5.94 | 5.16 | 10.21-10.32 | 5.54 | 14.68-14.79 | 5.92 |
| 4.93-4.94 | 4.79 | 5.95-5.99 | 5.17 | 10.33-10.44 | 5.55 | 14.80-14.91 | 5.93 |
| 4.95-4.96 | 4.80 | 6.00-6.04 | 5.18 | 10.45-10.56 | 5.56 | 14.92-15.03 | 5.94 |
| 4.97-4.98 | 4.81 | 6.05-6.09 | 5.19 | 10.57-10.68 | 5.57 | 15.04-15.15 | 5.95 |
| 4.99-5.00 | 4.82 | 6.10-6.15 | 5.20 | 10.69-10.79 | 5.58 | 15.16-15.26 | 5.96 |
| 5.01-5.02 | 4.83 | 6.16-6.22 | 5.21 | 10.80-10.91 | 5.59 | 15.27-15.38 | 5.97 |
| 5.03-5.04 | 4.84 | 6.23-6.30 | 5.22 | 10.93-11.03 | 5.60 | 15.39-15.50 | 5.98 |
| 5.05-5.06 | 4.85 | 6.31-6.40 | 5.23 | 11.04-11.15 | 5.61 | 15.51-15.62 | 5.99 |
| 5.07-5.08 | 4.86 | 6.41-6.57 | 5.24 | 11.16-11.26 | 5.62 | 15.63-15.73 | 6.00 |
| 5.09-5.10 | 4.87 | 6.58-6.91 | 5.25 | 11.27-11.38 | 5.63 | 15.74-15.85 | 6.01 |
| 5.11-5.12 | 4.88 | 6.92-7.03 | 5.26 | 11.39-11.50 | 5.64 | 15.86-15.97 | 6.02 |
| 5.13-5.14 | 4.89 | 7.04-7.15 | 5.27 | 11.51-11.62 | 5.65 | 15.98.16.09 | 6.03 |
| 5.15-5.17 | 4.90 | 7.16-7.26 | 5.28 | 11.63-11.73 | 5.66 | 16.10-16.20 | 6.04 |
| 5.18-5.19 | 4.91 | 7.27-7.38 | 5.29 | 11.74-11.85 | 5.67 | 16.21-16.32 | 6.05 |
| 5.20-5.21 | 4.92 | 7.39-7.50 | 5.30 | 11.86-11.97 | 5.68 | 16.33-16.44 | 6.06 |
| 5.22-5.23 | 4.93 | 7.51-7.62 | 5.31 | 11.98-12.09 | 5.69 | 16.45-16.56 | 6.07 |
| 5.24-5.26 | 4.94 | 7.63-7.73 | 5.32 | 12.10-12.20 | 5.70 | 16.57-16.67 | 6.08 |
| 5.27-5.28 | 4.95 | 7.74-7.85 | 5.33 | 12.21-12.32 | 5.71 | 16.68-16.70 | 6.09 |
| 5.29-5.31 | 4.96 | 7.86-7.97 | 5.34 | 12.33-12.44 | 5.72 | | |

Table 6

DERIVATION OF ACTUAL EVAPORATION FROM POTENTIAL FOR A ROOT CONSTANT OF 5.5 INCHES

| Potential in. | Actual in. | Potential in. | Actual in. | Potential in. | Actual in. | Potential in. | Actual in. |
|---|---|---|---|---|---|---|---|
| 6.30 | 6.30 | 7.02-7.03 | 6.67 | 9.68-9.79 | 7.05 | 14.15-14.26 | 7.43 |
| 6.31 | 6.30 | 7.04-7.06 | 6.68 | 9.80-9.90 | 7.06 | 14.27-14.37 | 7.44 |
| 6.32 | 6.31 | 7.07-7.08 | 6.69 | 9.91-10.02 | 7.07 | 14.38-14.49 | 7.45 |
| 6.33-6.34 | 6.32 | 7.09-7.11 | 6.70 | 10.03-10.14 | 7.08 | 14.50-14.61 | 7.46 |
| 6.35 | 6.33 | 7.12-7.13 | 6.71 | 10.15-10.26 | 7.09 | 14.62-14.73 | 7.47 |
| 6.36-6.37 | 6.34 | 7.14-7.16 | 6.72 | 10.27-10.38 | 7.10 | 14.74-14.85 | 7.48 |
| 6.38-6.39 | 6.35 | 7.17-7.19 | 6.73 | 10.39-10.49 | 7.11 | 14.86-14.96 | 7.49 |
| 6.40-6.41 | 6.36 | 7.20-7.22 | 6.74 | 10.50-10.61 | 7.12 | 14.97-15.08 | 7.50 |
| 6.42 | 6.37 | 7.23-7.25 | 6.75 | 10.62-10.73 | 7.13 | 15.09-15.20 | 7.51 |
| 6.43-6.44 | 6.38 | 7.26-7.28 | 6.76 | 10.74-10.85 | 7.14 | 15.21-15.32 | 7.52 |
| 6.45-6.46 | 6.39 | 7.29-7.31 | 6.77 | 10.86-10.96 | 7.15 | 15.33-15.43 | 7.53 |
| 6.47 | 6.40 | 7.32-7.34 | 6.78 | 10.97-11.08 | 7.16 | 15.44-15.55 | 7.54 |
| 6.48-6.49 | 6.41 | 7.35-7.37 | 6.79 | 11.09-11.20 | 7.17 | 15.56-15.67 | 7.55 |
| 6.50-6.51 | 6.42 | 7.38-7.41 | 6.80 | 11.21-11.31 | 7.18 | 15.68-15.79 | 7.56 |
| 6.52-6.53 | 6.43 | 7.42-7.44 | 6.81 | 11.32-11.43 | 7.19 | 15.80-15.90 | 7.57 |
| 6.54-6.55 | 6.44 | 7.45-7.48 | 6.82 | 11.44-11.55 | 7.20 | 15.91-16.02 | 7.58 |
| 6.56 | 6.45 | 7.49-7.51 | 6.83 | 11.56-11.67 | 7.21 | 16.03-16.14 | 7.59 |
| 6.57-6.58 | 6.46 | 7.52-7.55 | 6.84 | 11.68-11.79 | 7.22 | 16.15-16.26 | 7.60 |
| 6.59-6.60 | 6.47 | 7.56-7.60 | 6.85 | 11.80-11.90 | 7.23 | 16.27-16.37 | 7.61 |
| 6.61-6.62 | 6.48 | 7.61-7.64 | 6.86 | 11.91-12.02 | 7.24 | 16.38-16.49 | 7.62 |
| 6.63-6.64 | 6.49 | 7.65-7.69 | 6.87 | 12.03-12.14 | 7.25 | 16.50-16.61 | 7.63 |
| 6.65-6.66 | 6.50 | 7.70-7.74 | 6.88 | 12.15-12.26 | 7.26 | 16.62-16.73 | 7.64 |
| 6.67-6.68 | 6.51 | 7.75-7.79 | 6.89 | 12.27-12.38 | 7.27 | 16.74-16.85 | 7.65 |
| 6.69-6.70 | 6.52 | 7.80-7.85 | 6.90 | 12.39-12.49 | 7.28 | 16.86-16.96 | 7.66 |
| 6.71-6.72 | 6.53 | 7.86-7.92 | 6.91 | 12.50-12.61 | 7.29 | 16.97-17.08 | 7.67 |
| 6.73-6.74 | 6.54 | 7.93-8.00 | 6.92 | 12.62-12.73 | 7.30 | 17.09-17.20 | 7.68 |
| 6.75-6.76 | 6.55 | 8.01-8.10 | 6.93 | 12.74-12.85 | 7.31 | 17.21-17.32 | 7.69 |
| 6.77-6.78 | 6.56 | 8.11-8.27 | 6.94 | 12.86-12.96 | 7.32 | 17.33-17.43 | 7.70 |
| 6.79-6.80 | 6.57 | 8.28-8.61 | 6.95 | 12.97-13.08 | 7.33 | 17.44-17.55 | 7.71 |
| 6.81-6.82 | 6.58 | 8.62-8.73 | 6.96 | 13.09-13.20 | 7.34 | 17.56-17.67 | 7.72 |
| 6.83-6.84 | 6.59 | 8.74-8.85 | 6.97 | 13.21-13.32 | 7.35 | 17.68-17.79 | 7.73 |
| 6.85-6.87 | 6.60 | 8.86-8.96 | 6.98 | 13.32-13.43 | 7.36 | 17.80-17.90 | 7.74 |
| 6.88-6.89 | 6.61 | 8.97-9.08 | 6.99 | 13.44-13.55 | 7.37 | 17.91-18.02 | 7.75 |
| 6.90-6.91 | 6.62 | 9.09-9.20 | 7.00 | 13.56-13.67 | 7.38 | 18.03-18.14 | 7.76 |
| 6.92-6.93 | 6.63 | 9.21-9.32 | 7.01 | 13.68-13.79 | 7.39 | 18.15-18.26 | 7.77 |
| 6.94-6.96 | 6.64 | 9.33-9.43 | 7.02 | 13.80-13.90 | 7.40 | 18.27-18.37 | 7.78 |
| 6.97-6.98 | 6.65 | 9.44-9.55 | 7.03 | 13.91-14.02 | 7.41 | 18.38-18.49 | 7.79 |
| 6.99-7.01 | 6.66 | 9.56-9.67 | 7.04 | 14.03-14.14 | 7.42 | | |

Table 7

DERIVATION OF ACTUAL EVAPORATION FROM POTENTIAL FOR A ROOT CONSTANT OF 8.0 INCHES

| Potential in. | Actual in. | Potential in. | Actual in. | Potential in. | Actual in. | Potential in. | Actual in. |
|---|---|---|---|---|---|---|---|
| 8.80 | 8.80 | 9.52-9.53 | 9.17 | 12.18-12.29 | 9.55 | 16.65-16.76 | 9.93 |
| 8.81 | 8.80 | 9.54-9.56 | 9.18 | 12.30-12.40 | 9.56 | 16.77-16.87 | 9.94 |
| 8.82 | 8.81 | 9.57-9.58 | 9.19 | 12.41-12.52 | 9.57 | 16.88-16.99 | 9.95 |
| 8.83-8.84 | 8.82 | 9.59-9.61 | 9.20 | 12.53-12.64 | 9.58 | 17.00-17.11 | 9.96 |
| 8.85 | 8.83 | 9.62-9.63 | 9.21 | 12.65-12.76 | 9.59 | 17.12-17.23 | 9.97 |
| 8.86-8.87 | 8.84 | 9.64-9.66 | 9.22 | 12.77-12.88 | 9.60 | 17.24-17.35 | 9.98 |
| 8.88-8.89 | 8.85 | 9.67-9.69 | 9.23 | 12.89-12.99 | 9.61 | 17.36-17.46 | 9.99 |
| 8.90-8.91 | 8.86 | 9.70-9.72 | 9.24 | 13.00-13.11 | 9.62 | 17.47-17.58 | 10.00 |
| 8.92 | 8.87 | 9.73-9.75 | 9.25 | 13.12-13.23 | 9.63 | 17.59-17.70 | 10.01 |
| 8.93-8.94 | 8.88 | 9.76-9.78 | 9.26 | 13.24-13.35 | 9.64 | 17.71-17.82 | 10.02 |
| 8.95-8.96 | 8.89 | 9.79-9.81 | 9.27 | 13.36-13.46 | 9.65 | 17.83-17.93 | 10.03 |
| 8.97 | 8.90 | 9.82-9.84 | 9.28 | 13.47-13.58 | 9.66 | 17.94-18.05 | 10.04 |
| 8.98-8.99 | 8.91 | 9.85-9.87 | 9.29 | 13.59-13.70 | 9.67 | 18.06-18.17 | 10.05 |
| 9.00-9.01 | 8.92 | 9.88-9.91 | 9.30 | 13.71-13.81 | 9.68 | 18.18-18.29 | 10.06 |
| 9.02-9.03 | 8.93 | 9.92-9.94 | 9.31 | 13.82-13.93 | 9.69 | 18.30-18.40 | 10.07 |
| 9.04-9.05 | 8.94 | 9.95-9.98 | 9.32 | 13.94-14.05 | 9.70 | 18.41-18.52 | 10.08 |
| 9.06 | 8.95 | 9.99-10.01 | 9.33 | 14.06-14.17 | 9.71 | 18.53-18.64 | 10.09 |
| 9.07-9.08 | 8.96 | 10.02-10.05 | 9.34 | 14.18-14.29 | 9.72 | 18.65-18.76 | 10.10 |
| 9.09-9.10 | 8.97 | 10.06-10.10 | 9.35 | 14.30-14.40 | 9.73 | 18.77-18.87 | 10.11 |
| 9.11-9.12 | 8.98 | 10.11-10.14 | 9.36 | 14.41-14.52 | 9.74 | 18.88-18.99 | 10.12 |
| 9.13-9.14 | 8.99 | 10.15-10.19 | 9.37 | 14.53-14.64 | 9.75 | 19.00-19.11 | 10.13 |
| 9.15-9.16 | 9.00 | 10.20-10.24 | 9.38 | 14.65-14.76 | 9.76 | 19.12-19.23 | 10.14 |
| 9.17-9.18 | 9.01 | 10.25-10.29 | 9.39 | 14.77-14.88 | 9.77 | 19.24-19.35 | 10.15 |
| 9.19-9.20 | 9.02 | 10.30-10.35 | 9.40 | 14.89-14.99 | 9.78 | 19.36-19.46 | 10.16 |
| 9.21-9.22 | 9.03 | 10.36-10.42 | 9.41 | 15.00-15.11 | 9.79 | 19.47-19.58 | 10.17 |
| 9.23-9.24 | 9.04 | 10.43-10.50 | 9.42 | 15.12-15.23 | 9.80 | 19.59-19.70 | 10.18 |
| 9.25-9.26 | 9.05 | 10.51-10.60 | 9.43 | 15.24-15.35 | 9.81 | 19.71-19.82 | 10.19 |
| 9.27-9.28 | 9.06 | 10.61-10.77 | 9.44 | 15.36-15.46 | 9.82 | 19.83-19.93 | 10.20 |
| 9.29-9.30 | 9.07 | 10.78-11.11 | 9.45 | 15.47-15.58 | 9.83 | 19.94-20.05 | 10.21 |
| 9.31-9.32 | 9.08 | 11.12-11.23 | 9.46 | 15.59-15.70 | 9.84 | 20.06-20.17 | 10.22 |
| 9.33-9.34 | 9.09 | 11.24-11.35 | 9.47 | 15.71-15.82 | 9.85 | 20.18-20.29 | 10.23 |
| 9.35-9.37 | 9.10 | 11.36-11.46 | 9.48 | 15.83-15.93 | 9.86 | 20.30-20.40 | 10.24 |
| 9.38-9.39 | 9.11 | 11.47-11.58 | 9.49 | 15.94-16.05 | 9.87 | 20.41-20.52 | 10.25 |
| 9.40-9.41 | 9.12 | 11.59-11.70 | 9.50 | 16.06-16.17 | 9.88 | 20.53-20.64 | 10.26 |
| 9.42-9.43 | 9.13 | 11.71-11.82 | 9.51 | 16.18-16.29 | 9.89 | 20.65-20.76 | 10.27 |
| 9.44-9.46 | 9.14 | 11.83-11.93 | 9.52 | 16.30-16.40 | 9.90 | 20.77-20.87 | 10.28 |
| 9.47-9.48 | 9.15 | 11.94-12.05 | 9.53 | 16.41-16.52 | 9.91 | 20.88-20.99 | 10.29 |
| 9.49-9.51 | 9.16 | 12.06-12.17 | 9.54 | 16.53-16.64 | 9.92 | | |